US008632131B2

(12) **United States Patent**
Humbert

(10) **Patent No.: US 8,632,131 B2**
(45) **Date of Patent: Jan. 21, 2014**

(54) **TENSIONING APPARATUSES FOR OCCUPANT RESTRAINT SYSTEMS AND ASSOCIATED SYSTEMS AND METHODS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/647,198**

(22) Filed: **Oct. 8, 2012**

(65) **Prior Publication Data**

US 2013/0127229 A1 May 23, 2013

Related U.S. Application Data

(62) Division of application No. 12/569,522, filed on Sep. 29, 2009, now Pat. No. 8,303,043.

(60) Provisional application No. 61/101,085, filed on Sep. 29, 2008.

(51) **Int. Cl.**

B60R 21/01	(2006.01)
B60R 21/00	(2006.01)
B60R 22/00	(2006.01)

(52) **U.S. Cl.**
USPC **297/477**; 297/484

(58) **Field of Classification Search**
USPC 297/477, 484, 216.1, 479, 476, 474; 280/807
See application file for complete search history.

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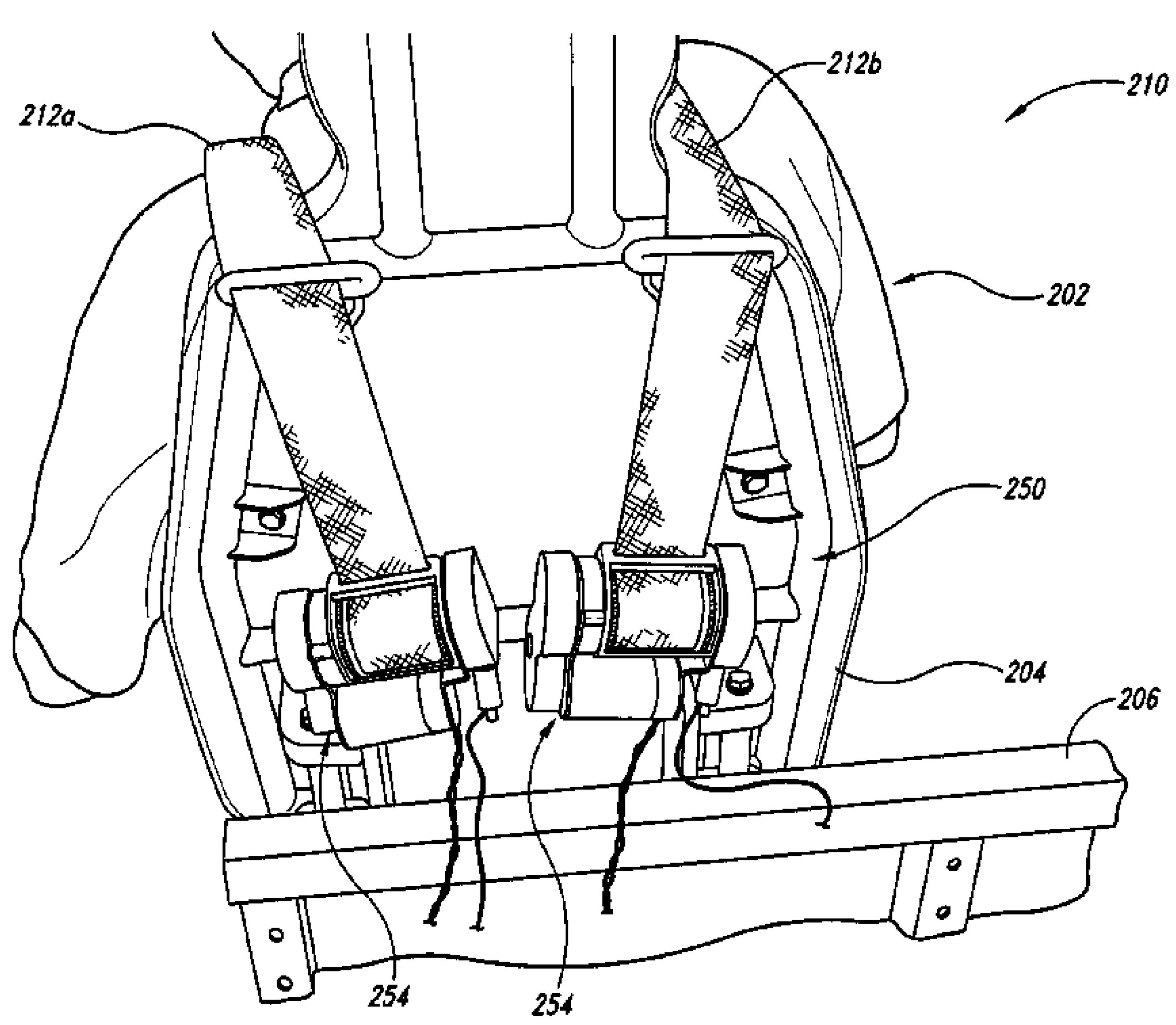
(57) **ABSTRACT**

Tensioning apparatuses for occupant restraint systems and associated systems and methods. In one embodiment, an occupant restraint system for a vehicle can include a flexible web configured to extend across at least a portion of an occupant seated in the vehicle and an electrically actuated web retractor operably coupled to a proximal end portion of the web. The web retractor is configured to automatically wind and unwind the web. The system also includes an acceleration sensor operably coupled to the electrically actuated web retractor. The acceleration sensor is configured to send an electrical signal to the web retractor in response to a vehicle acceleration above a preset magnitude. In response to the signal, the web retractor is configured to (a) retract the web, and/or (b) at least temporarily prevent the web from moving inwardly or outwardly.

7 Claims, 8 Drawing Sheets



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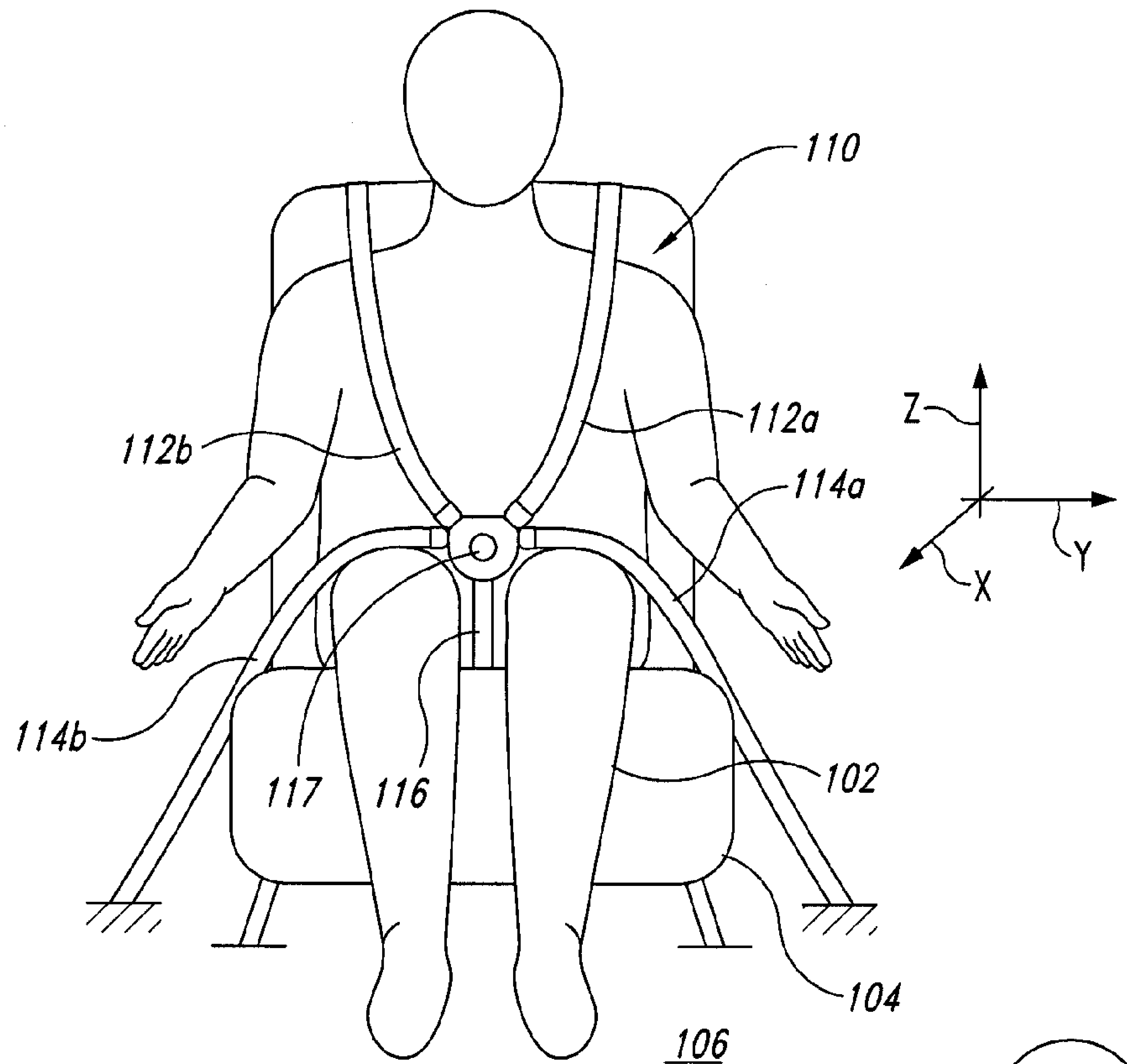
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Z
Y
X
112a
112b
114a
114b
117
116
102
104
106

Fig. 1A

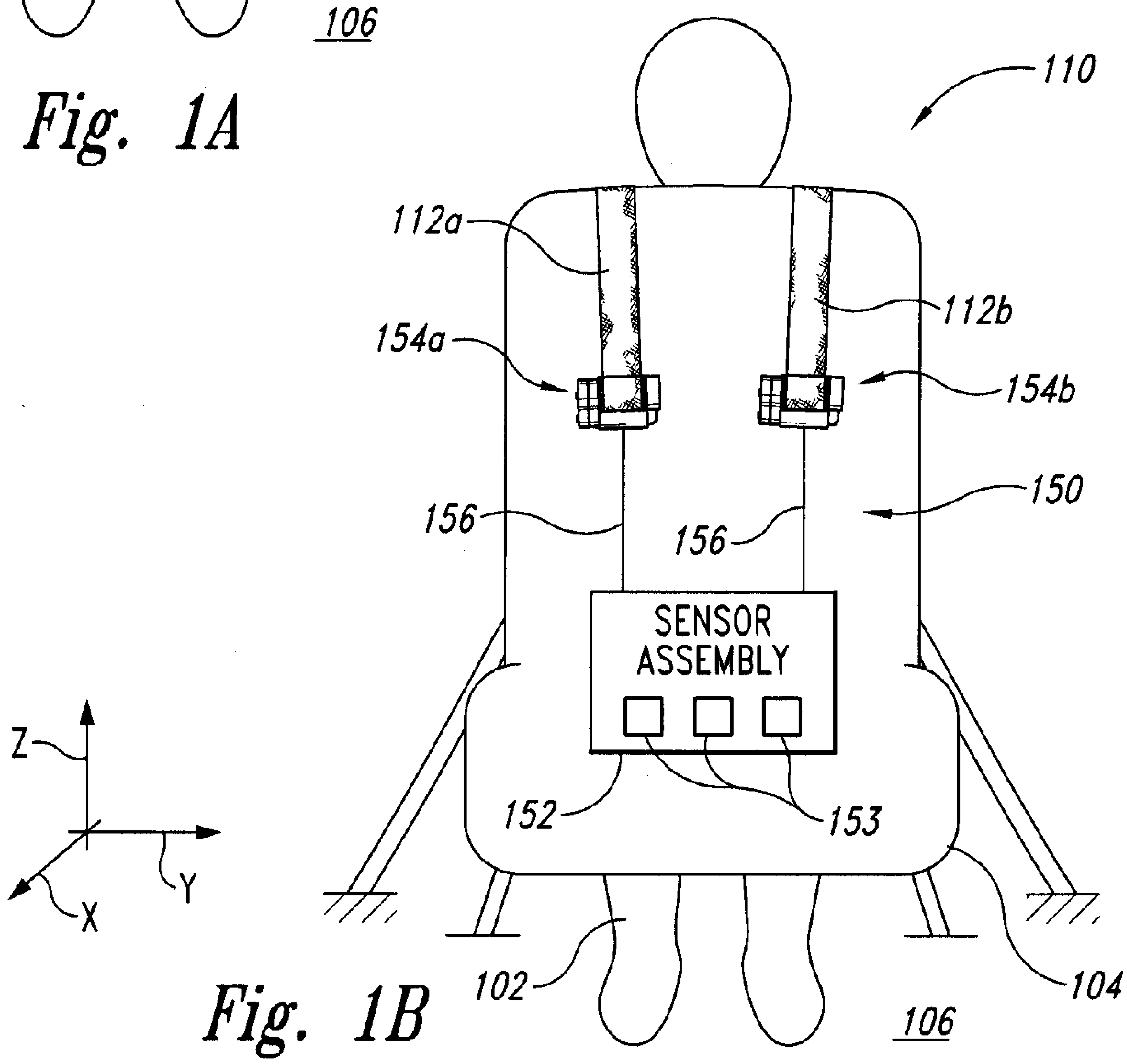

110
112a
112b
154a
154b
156
156
150
SENSOR ASSEMBLY
152
153
Z
Y
X
102
104
106

Fig. 1B

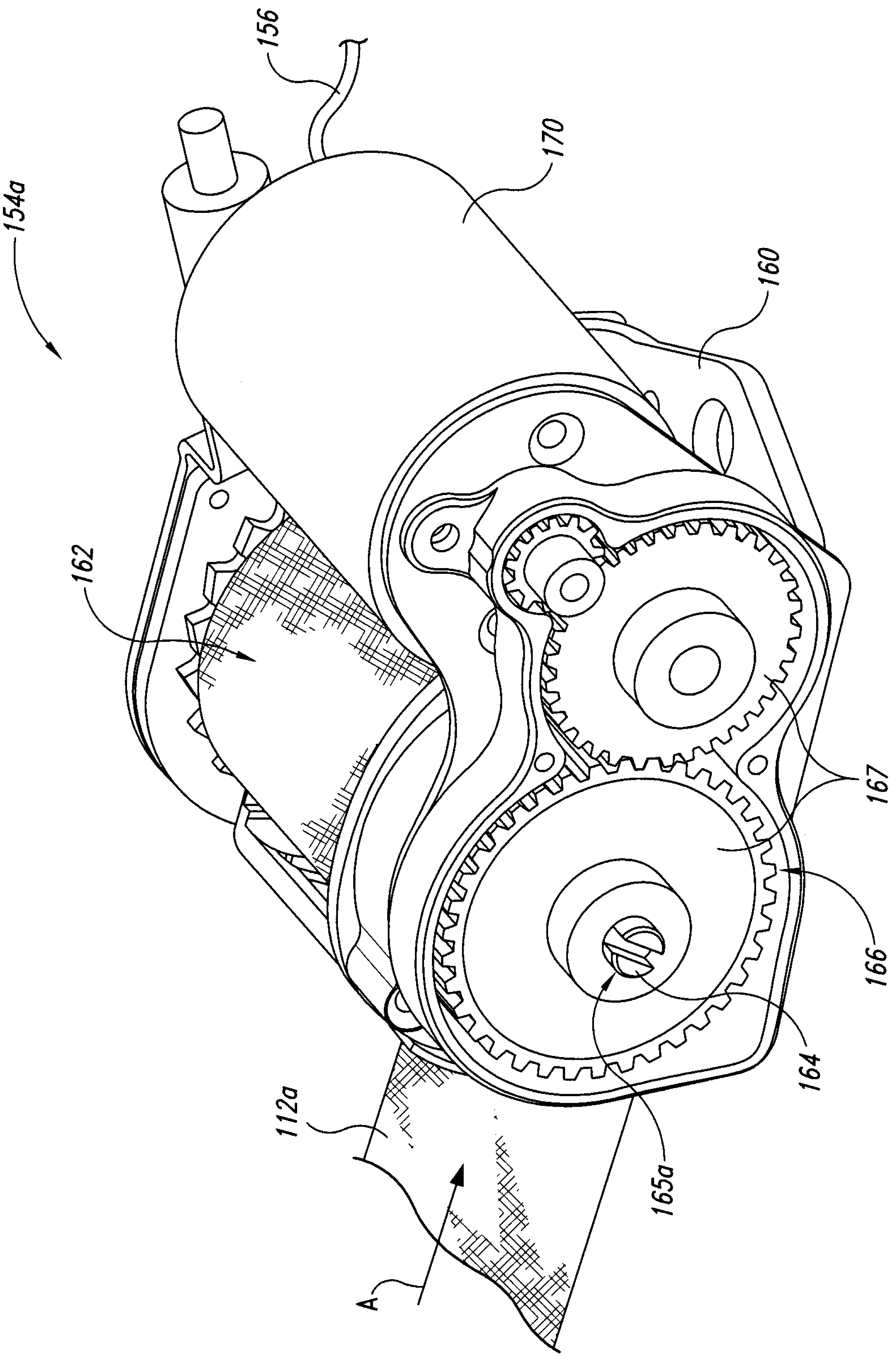


Fig. 2A

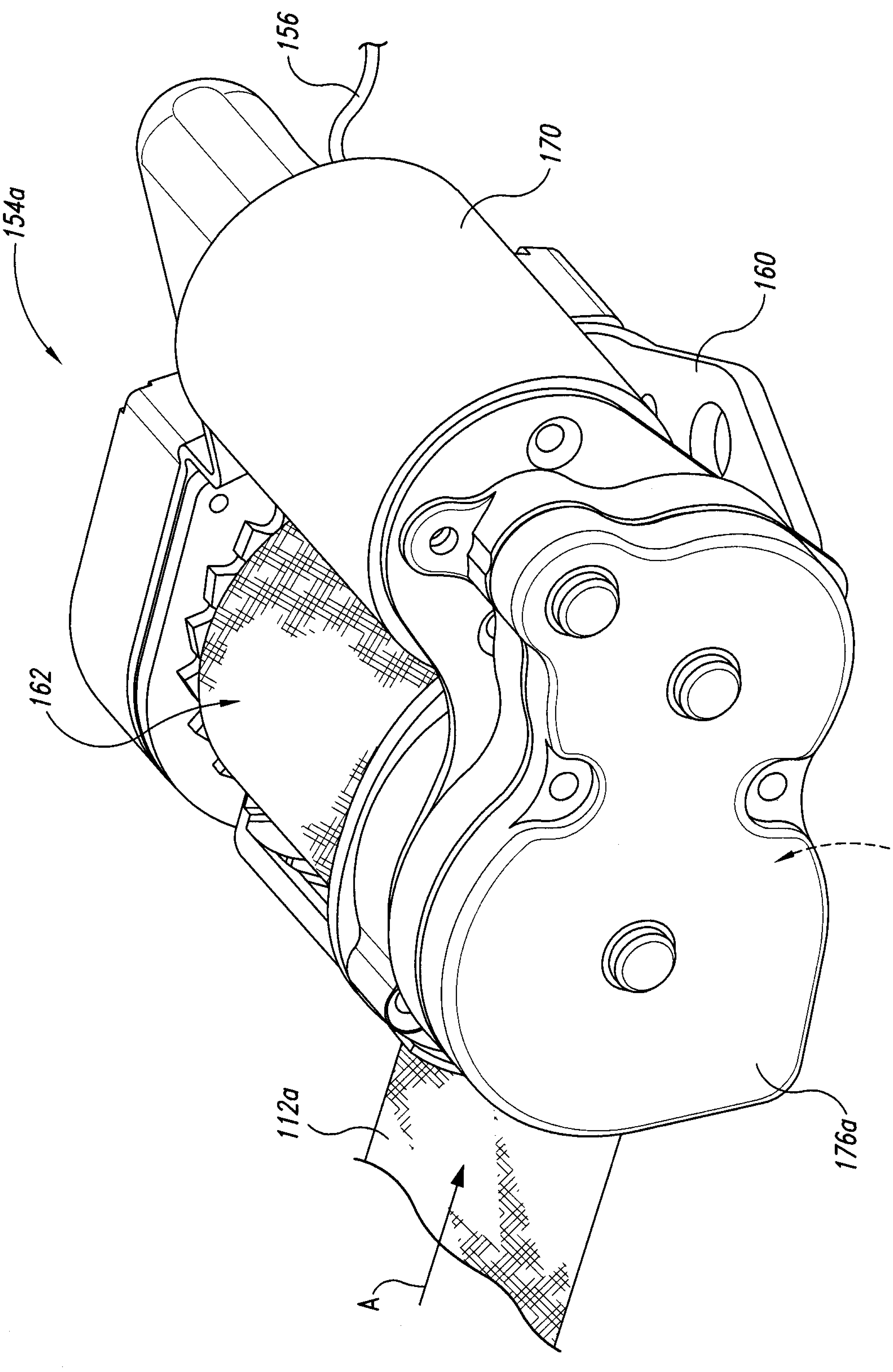


Fig. 2B

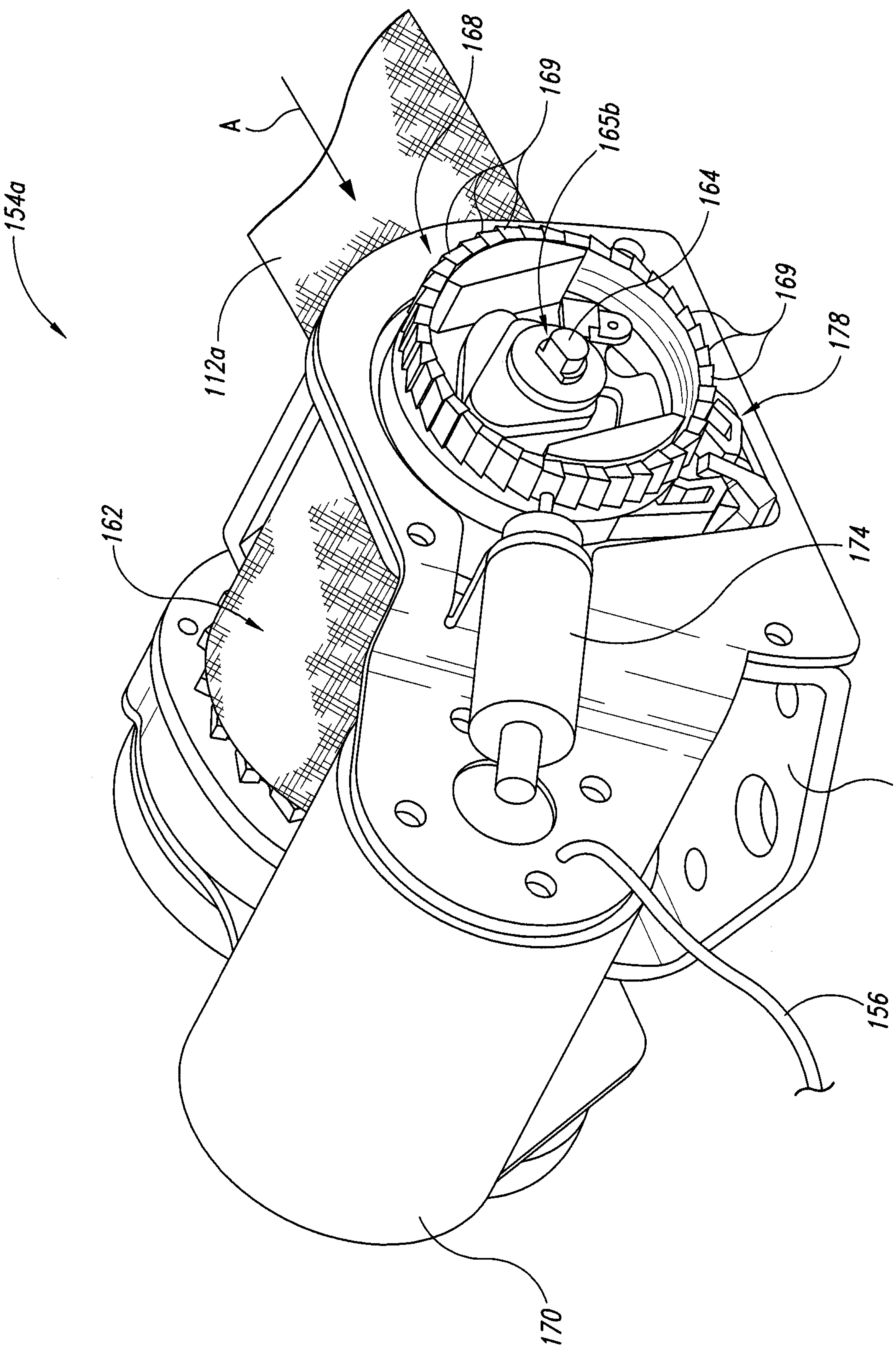


Fig. 2C

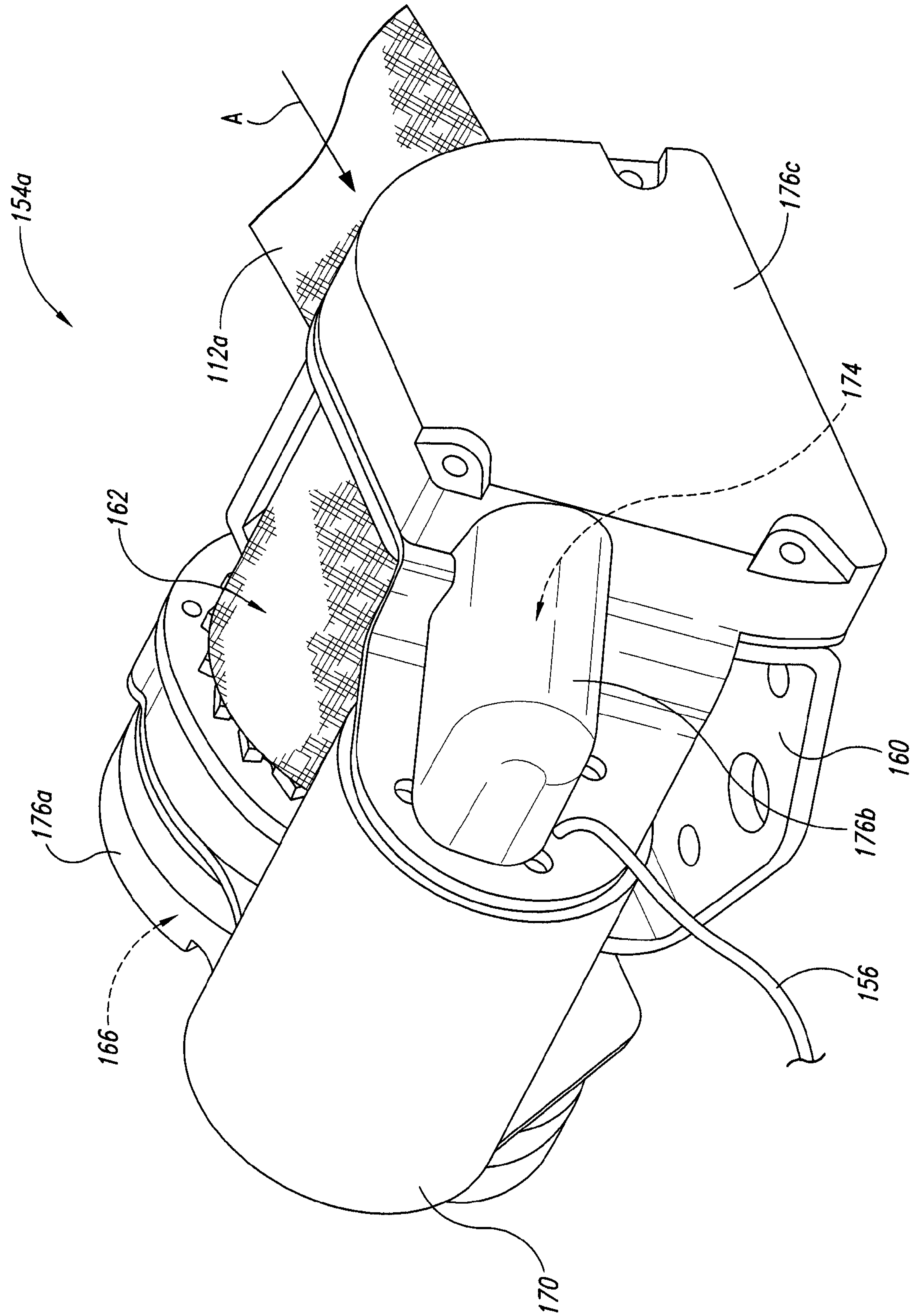
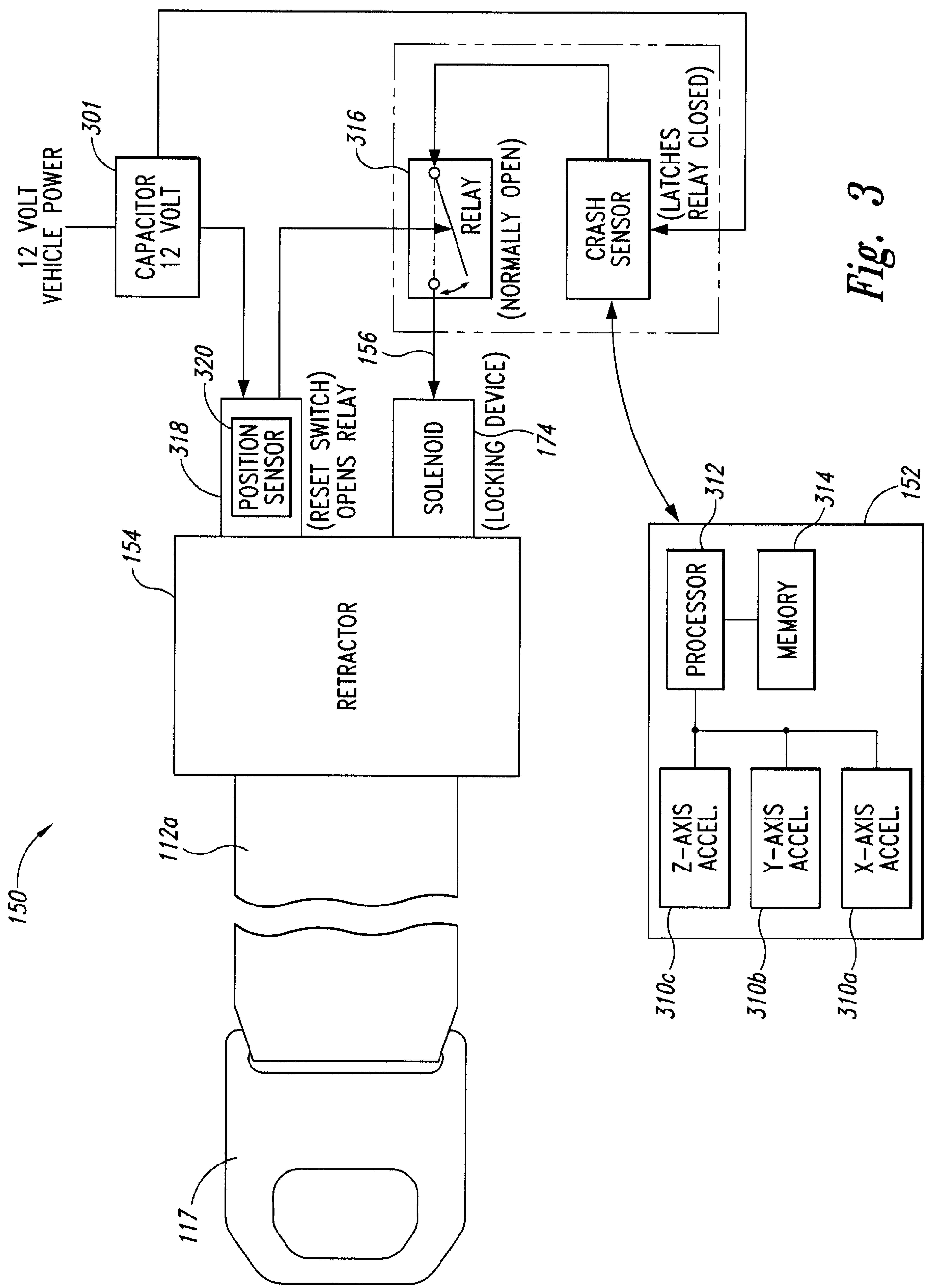


Fig. 2D



12 VOLT
VEHICLE POWER
301
CAPACITOR
12 VOLT
316
RELAY
(NORMALLY OPEN)
CRASH
SENSOR
(LATCHES
RELAY CLOSED)
320
318
POSITION
SENSOR
(RESET SWITCH)
OPENS RELAY
156
SOLENOID
(LOCKING DEVICE)
174
154
RETRACTOR
312
PROCESSOR
314
MEMORY
152
Z-AXIS
ACCEL.
Y-AXIS
ACCEL.
X-AXIS
ACCEL.
310c
310b
310a
150
112a
117

Fig. 3

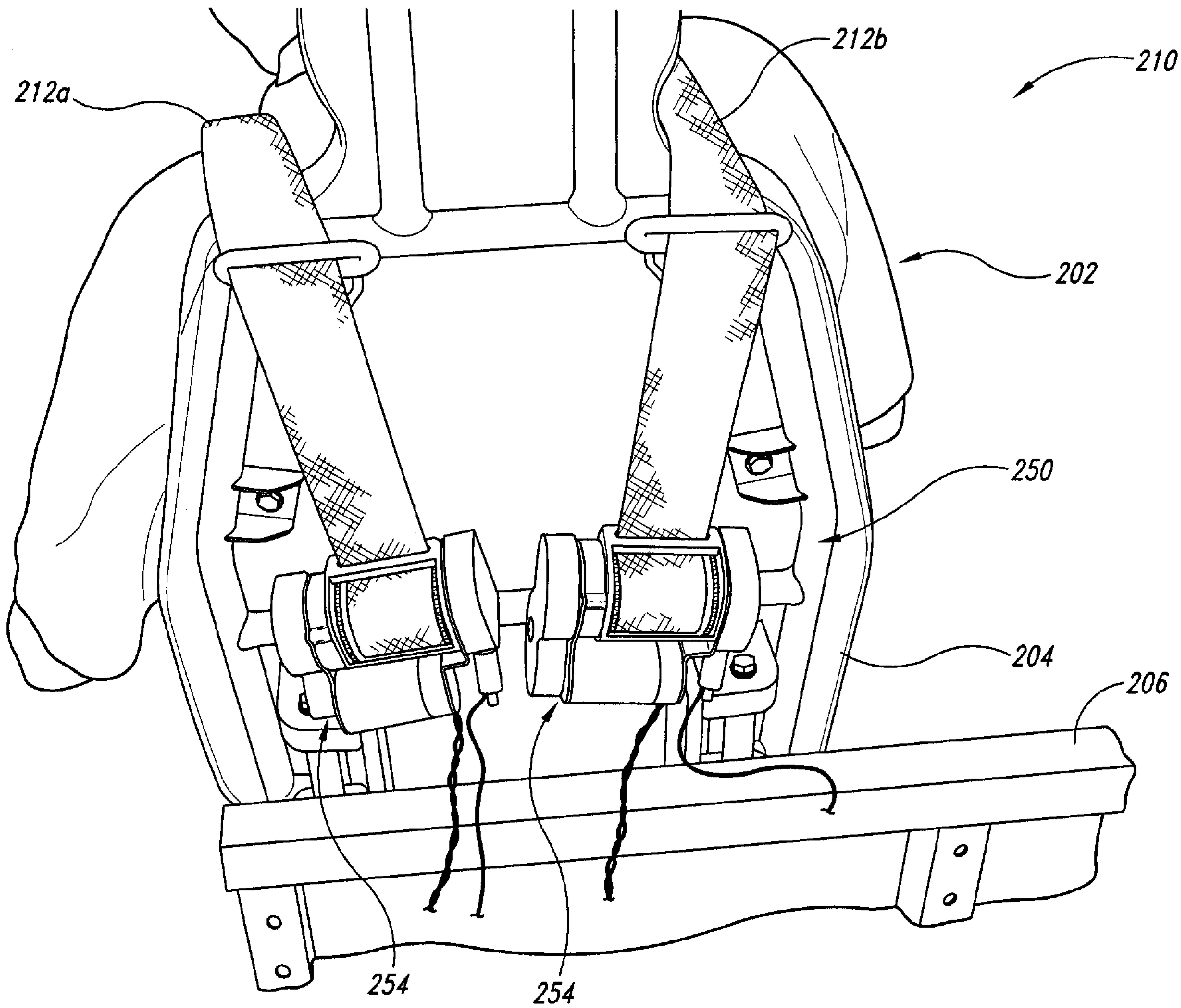


Fig. 4A

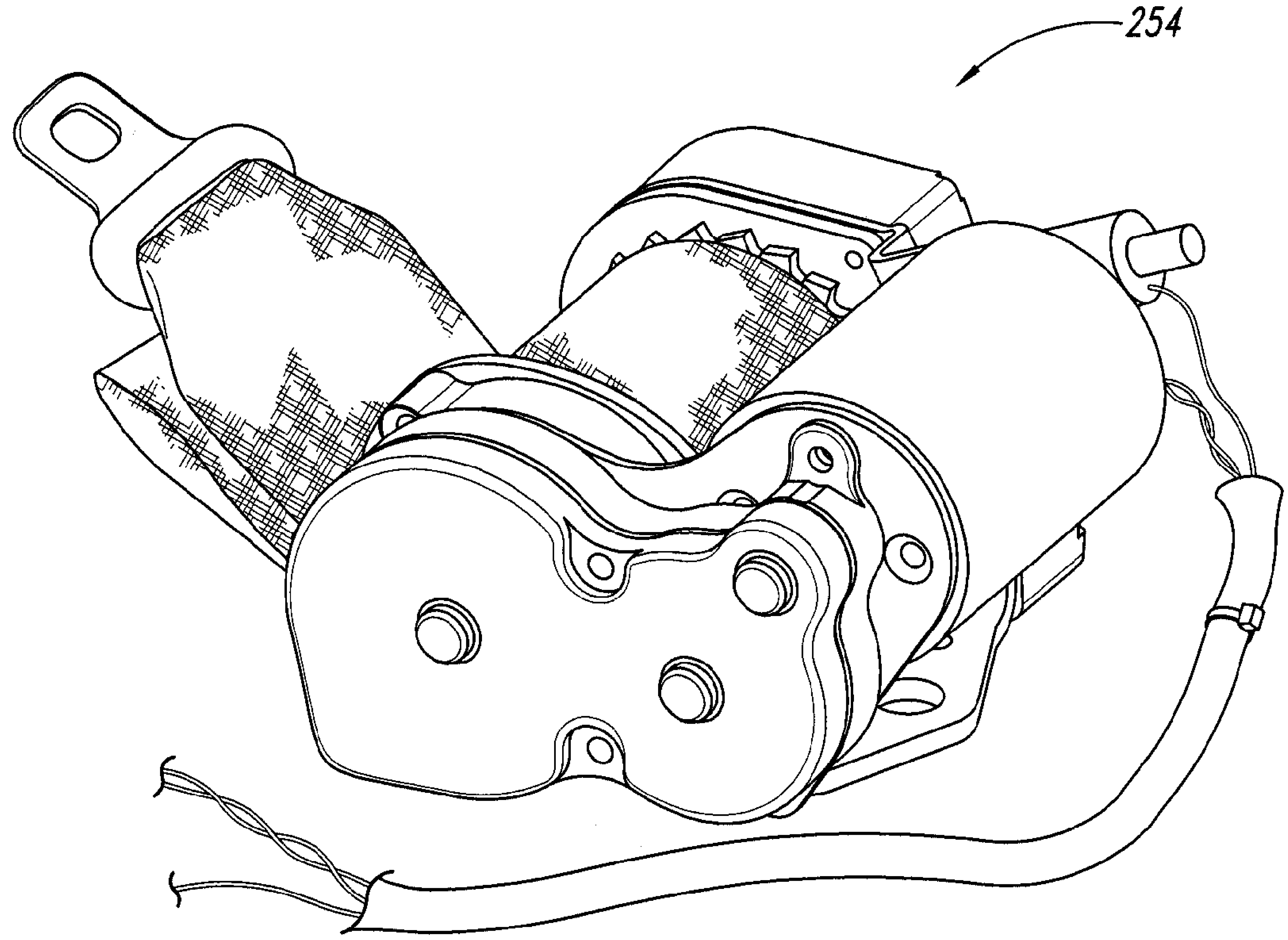


Fig. 4B

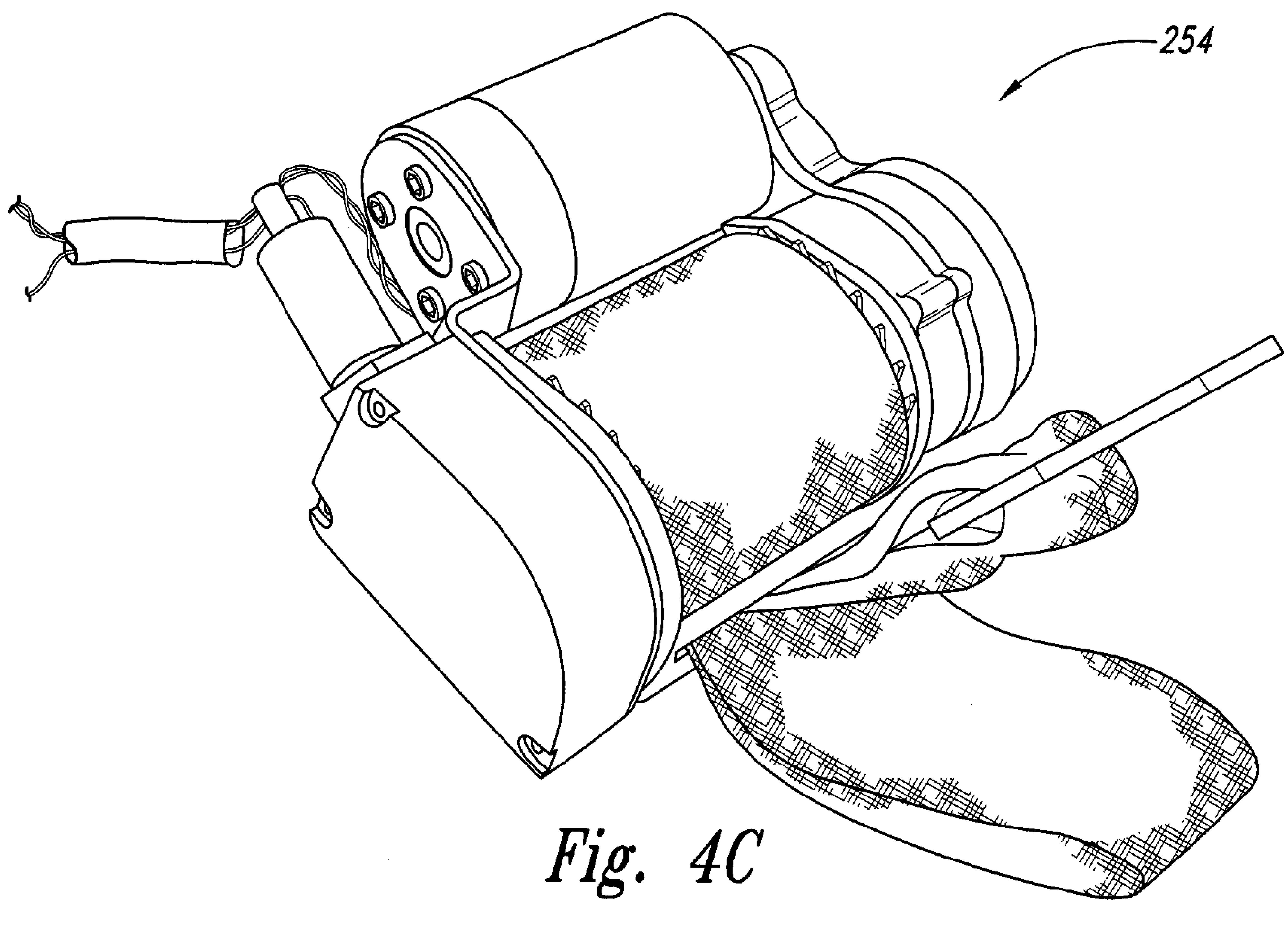


Fig. 4C

TENSIONING APPARATUSES FOR OCCUPANT RESTRAINT SYSTEMS AND ASSOCIATED SYSTEMS AND METHODS

CROSS REFERENCE TO APPLICATIONS INCORPORATED HEREIN BY REFERENCE

This application is a divisional of U.S. patent application Ser. No. 12/569,522, filed Sep. 29, 2009, which claims the benefit of U.S. Provisional Patent Application No. 61/101,085, filed Sep. 29, 2008, the disclosures of which are incorporated herein by reference in their entireties.

This application is also related to U.S. Provisional Patent Application No. 61/029,292 entitled PERSONAL RESTRAINT SYSTEMS AND ASSOCIATED TENSIONING APPARATUSES, filed Feb. 15, 2008, and incorporated herein by reference in its entirety.

TECHNICAL FIELD

The following disclosure relates generally to tensioning apparatuses for occupant restraint systems and associated systems and methods.

BACKGROUND

Conventional occupant restraint systems, such as those used in passenger vehicles, typically include one or more webs or belts to restrain passengers in their seats. One type of restraint system, for example, includes a shoulder, web and a lap web. Other restraint systems have more than two webs (e.g., two shoulder webs, a lap web, and a crotch web) to more adequately restrain passengers during impacts that can cause dislocation of the passengers in the vertical direction.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A and **1**B are partially schematic front and back views, respectively, of an occupant restraint system having a web tensioning subsystem configured in accordance with an embodiment of the disclosure.

FIGS. **2**A-**2**D are isometric views of a web retractor having an electrically activated web tensioning device configured in accordance with an embodiment of the disclosure.

FIG. **3** is a schematic diagram of the web tensioning subsystem of FIGS. **1**A and **1**B configured in accordance with an embodiment of the disclosure.

FIGS. **4**A-**4**C illustrate a portion of an occupant restraint system including a web tensioning subsystem configured in accordance with another embodiment of the disclosure.

DETAILED DESCRIPTION

The present disclosure describes tensioning apparatuses for occupant restraint systems and associated systems and methods. Many specific details are set forth in the following description and in FIGS. **1**A-**4**C to provide a thorough understanding of various embodiments of the disclosure. Other details describing well-known structures and systems often associated with restraint systems and related vehicle structures, however, are not set forth below to avoid unnecessarily obscuring the description of the various embodiments of the disclosure.

Many of the details and features shown in the Figures are merely illustrative of particular embodiments of the disclosure. Accordingly, other embodiments can have other details and features without departing from the spirit and scope of the present disclosure. In addition, those of ordinary skill in the art will understand that further embodiments can be practiced without several of the details described below. Furthermore, various embodiments of the disclosure can include structures other than those illustrated in the Figures and are expressly not limited to the structures shown in the Figures. Moreover, the various elements and features illustrated in the Figures may not be drawn to scale.

FIGS. **1**A and **1**B are front and back views, respectively, of an occupant restraint system **110** having a web tensioning subsystem **150** configured in accordance with an embodiment of the disclosure. Referring to FIGS. **1**A and **1**B together, the occupant restraint system **110** ("restraint system **110**") secures an occupant **102** to a seat **104** in a vehicle **106**. Suitable vehicles **106** can include ground vehicles, automobiles, military vehicles, aircraft, rotorcraft, watercraft, spacecraft, and other suitable land, sea, and air vehicles). As described in greater detail below, the web tensioning subsystem **150** is configured to control operation of certain aspects of the restraint system **110** to automatically adjust or modulate the tension of the restraint system in response to predetermined dynamic events and/or forces (e.g., rollovers, rough terrain, rapid decelerations and/or accelerations, collisions, impacts, etc.).

In the illustrated embodiment, the restraint system **110** includes a plurality of webs or belts extending around the occupant **102** and operably coupled to the vehicle **106** and/or the web tensioning subsystem **150**. As used herein, "webs" can include any type of flexible straps or belts, such as seat belts made from woven material as is known in the art for use with personal restraint systems. In the illustrated embodiment, for example, the restraint system **110** is a five-point restraint system including shoulder webs **112** (identified individually as a first shoulder web **112***a* and a second shoulder web **112***b*), lap webs **114** (identified individually as a first lap web **114***a* and a second lap web **116***b*), and a crotch web **116** operably coupled to a buckle assembly **117**. In other embodiments, however, the restraint system **110** can have other configurations. For example, the restraint system **110** can include a three-point or four-point restraint system. In still other embodiments, a single lap web **114** and/or a single shoulder web **118** may be used. Accordingly, the present disclosure is not limited to the particular web configurations disclosed herein.

As best seen in FIG. **1**B, the web tensioning subsystem **150** includes a sensor assembly **152** (shown schematically) and one or more web retractors **154** (two are shown as a first web retractor **154***a* and a second web retractor **154***b*). A proximal end portion of the first shoulder web **112***a* is operably coupled to the first web retractor **154***a*, and a proximal end portion of the second shoulder web **112***b* is operably coupled to the second web retractor **154***b*. The first and second web retractors **154***a* and **154***b* are fixedly attached to a rear portion of the seat **104**. The first and second web retractors **154***a* and **154***b* are each electrically coupled to the sensor assembly **152** with an electrical link **156** (e.g., a wire, electrical line, connector, etc.).

In the illustrated embodiment, the first and second web retractors **154***a* and **154***b* are positioned behind the seat **104**. In other embodiments, however, web retractors **154** can be positioned at different locations in the vehicle **106**, such as to the side of the seat **104**, above the seat **104**, etc. Moreover, although only two web retractors **154** are shown in the illustrated embodiment, a different number of web retractors **154** can be operably coupled to the shoulder webs **112** and/or the lap webs **114**. For example, a third web retractor **154** can be operably coupled to the lap webs **114** in addition to the illustrated web retractors **154***a* and **154***b* operably coupled to the shoulder webs **112**.

The sensor assembly **152** can include one or more acceleration sensors **153** (e.g., accelerometers) configured to sense vehicle accelerations (and decelerations) in one or more directions and send associated control signals to the web retractors **154**. For example, the sensor assembly **152** can include at least one acceleration sensor configured to sense vehicle accelerations in the vertical direction along the Z axis and one or more additional sensors configured to sense accelerations in the fore and aft directions along the X axis and/or laterally along the Y axis. In other embodiments, the web tensioning subsystem **150** can have a different arrangement and/or include different features. For example, the web tensioning subsystem **150** can include one or more additional web retractors **154** coupled to other webs. In addition, the web retractors **154** and/or sensor assembly **160** can be positioned at other locations on the seat **104** or vehicle **106**. Moreover, the sensor assembly **152** can include different features and/or have a different number of acceleration sensors.

Referring back to FIGS. **1**A and **1**B together, the shoulder webs **112** and other webs (e.g., lap webs **114**, crotch web **116**, etc.) can include features typically associated with conventional webs and safety belts. For example, the shoulder webs **112** and lap webs **114** can each include flexible segments of a fixed length and/or adjustable length to accommodate different sized occupants. In the illustrated embodiment, the lap webs **114** and crotch web **116** are fixedly secured to the seat **104** (e.g., to a seat frame and/or directed to the vehicle **106**), and the shoulder webs **112** are operably coupled to the web tensioning subsystem **150**. In other embodiments, however, the lap webs **114** and/or crotch web **116** can also be attached to the web tensioning subsystem **150** or another retractor (e.g., inertial reel) to automatically adjust the fit of the webs in response to movement of the occupant **102**. In still other embodiments, lap webs **114** and/or other webs may be manually adjusted, static, etc.

FIGS. **2**A-**2**D are isometric views of the first web retractor **154***a* before installation with the vehicle **106**. More specifically, FIGS. **2**A and **2**C are partially transparent left and right isometric views, respectively, of the first web retractor **154***a*, and FIGS. **2**B and **2**D are non-transparent left and right isometric views, respectively. Although only the first web retractor **154***a* is shown in FIGS. **2**A-**2**D, the first and second web retractors **154***a* and **154***b* can be at least generally similar in structure and function.

Referring to FIGS. **2**A-**2**D together, the first web retractor **154***a* includes a base or mounting bracket **160** that is fixedly attached to the vehicle **106** (e.g., a frame of the seat **104** of FIGS. **1**A and **1**B, a vehicle frame, a vehicle mount, etc.) and provides a secure base for the components of the web retractor. A spool **162** is carried by and rotatably mounted to the base **160**. The spool **162** is configured to receive a web or belt (e.g., the first shoulder web **112***a*) and wind and unwind the webbing during normal operation, as well as lock the webbing in place in the event of a sudden dynamic event to prevent the webbing from being released from the spool. The first web retractor **154***a* can also include an actuator **170** (e.g., a DC electric motor, linear motor, rotary motor, etc.) to control operation of the spool **162**. In other embodiments, the actuator **170** can include other suitable electrical, mechanical, pneumatic, hydraulic, and/or electromechanical devices in addition to, or in lieu of, the DC motor in the illustrated embodiment.

The spool **162** is fixedly attached to a rotating shaft **164** having (a) a first end **165***a* operably coupled to a gear assembly **166** (FIG. **2**A), and (b) a second end **165***b* operably coupled to a locking wheel **168** (FIG. **2**C). The gear assembly **166** can include, for example, one or more gears **167** positioned to provide a gear reduction for increased torque between the actuator **170** and the shaft **164**. The locking wheel **168** includes a plurality of teeth **169** spaced about a perimeter thereof. The first web retractor **154***a* can also include a solenoid **174** configured to lock/unlock the spool **162** in response to electrical signals from the sensor assembly **152**. As best seen in FIGS. **2**B and **2**D, the gear assembly **166** can be positioned within a first housing **176***a*, the solenoid **174** can be positioned within a second housing **176***b*, and the locking wheel **168** can be positioned within a third housing **176***c*.

In operation, the first web retractor **154***a* is configured to adapt or modulate the tension of the restraint system **110** (FIGS. **1**A and **1**B) in response to a detected predetermined event by activating the spool **162** and winding up, locking, or paying out the webbing (e.g., the first shoulder web **112***a*). More specifically, the sensor(s) **153** of the sensor assembly **152** (FIG. **1**B) can sense a vehicle acceleration above a preset magnitude (e.g., during a rollover, impact, collision, rapid deceleration or acceleration, etc.). The sensor assembly **152** sends a corresponding electrical signal to the first web retractor **154***a* via the link **156**. The actuator **170** responds to the signal by rotating the spool **162** and retracting the first shoulder web **112***a* in the direction of arrow A to tension the shoulder web. In some instances, the electrical signal can also energize the solenoid **174** and cause the teeth **169** of the locking wheel **168** to engage an engagement structure **178** (as best seen in FIG. **2**C) and prevent the spool **162** from rotating. This can prevent the spool **162** from paying out any webbing during the event. After the predetermined event, the actuator **170** can rotate the spool **162** in the other direction and extend the first shoulder web **112***a* in a direction opposite to the arrow A to reduce and/or restore the pre-event tension of the first shoulder web **112***a*. In this manner, the first web retractor **154***a* (as well as the other web retractors **154**) can repeatedly increase and decrease the tension of the shoulder webs **112** in response to different predetermined events and/or conditions.

FIG. **3** is a schematic diagram of a portion of the web tensioning subsystem **150** described above with reference to FIGS. **1**A-**2**D. During vehicle operation, a vehicle power circuit **301** provides power (e.g., 12-volt and/or 24-volt vehicle power) to the sensor assembly **152**. In the illustrated embodiment, the sensor assembly **152** can include an X-axis sensor **310***a* for sensing vehicle accelerations in the fore/aft or X direction, a Y-axis sensor **310***b* for sensing vehicle accelerations in the left/right or Y direction, and a Z-axis sensor **310***c* for sensing vehicle accelerations in the vertical or Z direction. The sensors **310***a-c* are operably coupled to a processor **312** and memory **314**, and configured to send corresponding acceleration information to the processor **312**. In operation, the processor **312** can process the information in accordance with computer-readable instructions stored on the memory **314**. More specifically, the processor **312** can determine if the acceleration(s) exceed a preset magnitude and, if so, the processor **312** can send a corresponding signal to the web retractor **154** via an activation circuit **316**. The components of the subsystem **150** can be operably coupled to each other with wired, wireless, fiber optic, and/or other links to control operation of the subsystem **150**.

During normal vehicle operation, the activation circuit **316** disables the sensor assembly **152** and the web retractor **154**. When the vehicle experiences an acceleration of above a predetermined magnitude in the X, Y, and/or Z direction (e.g., during a rollover), the sensor assembly **152** activates the activation circuit **316** and transmits an electrical signal to the web retractor **154** via the link **156**. As described above, the electrical signal causes the web retractor **154** to at least temporarily lock the spool **162** (FIG. **2**A) and prevent further extension of the web **112***a*. After the duration of the event, or if the forces associated with the predetermined event decreases, the sensor assembly **152** can notify the web retractor **154** to adjust (e.g., increase or decrease), and/or restore the tension to the attached web **112***a*. In the illustrated embodiment, for example, the web retractor **154** remains locked for a preset time or until a reset switch **318** deactivates the activation circuit **316**, de-energizing the web retractor **154**. The reset switch **318** can include a position sensor **320** operably coupled to the web retractor **154**.

In other embodiments, the web tensioning subsystem **150** can include different features and/or have a different configuration. For example, although the web tensioning subsystem **150** illustrated in FIG. **3** shows the components of the device operably coupled to each other, one skilled in the art will appreciate that a number of the components of the subsystem **150** may be combined or included in a single component.

FIGS. **4**A-**4**C illustrate a portion of an occupant restraint system **210** including a web tensioning subsystem **250** configured in accordance with another embodiment of the disclosure. More specifically, FIG. **4**A is a back view of the occupant restraint system **210** and web tensioning subsystem **250**. The restraint system **210** also includes a plurality of webs or belts (only two shoulder webs **212***a* and **212***b* are shown) extending around the occupant **202** to releasably secure the occupant **202** to a seat **204** in a vehicle **206**. In the illustrated embodiment, for example, restraint system **210** is a five-point restraint system generally similar to the restraint system **110** described above with reference to FIGS. **1**A and **1**B). The web tensioning subsystem **250** can include, for example, two web retractors **254** having electrically activated web tensioning devices and a sensor assembly (not shown). In the illustrated embodiment, the web retractors **254** are fixedly attached to a frame of the seat **204**.

FIGS. **4**B and **4**C are left and right isometric views, respectively, of one of the web retractors **254** before installation with the seat **204**. The web retractors **254** can be generally similar to the web retractors **154** described above with reference to FIGS. **1**A-**2**D, and can function in generally the same way.

The web tensioning subsystems **150** and **250** described above can be configured to provide different amounts of tension to the corresponding webs (e.g., the shoulder webs **112**) based on different corresponding predetermined events. For example, the web retractors **154***a-b* can partially and/or fully retract the shoulder webs **112** to provide different amounts of tension. By way of illustration, when the web tensioning subsystem **150** is employed in an automobile, the web tensioning subsystem **150** can tension the shoulder webs **112** with a first force in response to driving the automobile on rough or uneven terrain. After the rough terrain, the web tensioning subsystem **150** can restore the shoulder webs **112** to their original tensions. If the automobile rolls over or is in an accident, however, the web tensioning subsystem **150** can provide a second force greater than the first force, to restrain the occupant **102** in the seat **104**. Moreover, instead of providing discrete amounts of tension, in other embodiments, the web tensioning subsystem **150** can provide an amount of tension that is proportional to the severity of the predetermined event.

One advantage of the restraint systems and associated web tensioning subsystems described above and disclosed herein is that they can secure an occupant in their seat when the vehicle experiences a rapid deceleration, acceleration, impact, collision, rollover, etc. Another advantage of the tensioning apparatuses described above is that they can adjust the tension of the attached webs in response to different predetermined events, and restore the webs to their original tension after the predetermined events. A further advantage of the tensioning apparatuses described above is that they can repeatedly adjust the tension of the attached webs in response to the different predetermined events.

From the foregoing, it will be appreciated that specific embodiments have been described herein for purposes of illustration, but that various modifications may be made without deviating from the spirit and scope of the various embodiments of the disclosure. For example, the occupant restraint systems described above with reference to FIGS. **1**-**4**C may have different configurations and/or include different features. Moreover, specific elements of any of the foregoing embodiments can be combined or substituted for elements in other embodiments. For example, the occupant restraint systems described in the context of specific vehicles (e.g., automobile or aircraft systems) can be implemented in a number of other types of vehicles (e.g., non-automobile or non-aircraft systems). Certain aspects of the disclosure are accordingly not limited to automobile or aircraft systems. Furthermore, while advantages associated with certain embodiments of the disclosure have been described in the context of these embodiments, other embodiments may also exhibit such advantages, and not all embodiments need necessarily exhibit such advantages to fall within the scope of the invention. Accordingly, the disclosure is not limited, except as by the appended claims.

I claim:

1. An occupant restraint system for use in a vehicle, the occupant restraint system comprising:

a plurality of elongate webs configured to extend across at least a portion of an occupant seated in a seat carried by a vehicle;

a first electrically actuated web retractor operably coupled to a proximal end portion of one of the webs;

a second electrically actuated web retractor operably coupled to a proximal end portion of another one of the webs, wherein the first and second web retractors are configured to automatically wind and unwind the respective webs; and

a sensor assembly electrically coupled to the first and second electrically actuated web retractors, wherein the sensor assembly includes one or more acceleration sensors configured to sense vehicle accelerations and decelerations in one or more directions,

wherein the sensor assembly is configured to send electrical signals to the first and second web retractors in response to a dynamic event resulting in a vehicle acceleration above a predetermined threshold value, and wherein, in response to receiving the electrical signals from the sensor assembly, the first and second web retractors are configured to (a) automatically increase tension in the corresponding webs, and/or (b) prevent the corresponding webs from moving inwardly or outwardly.

2. The occupant restraint system of claim **1** wherein the plurality of elongate webs comprises a five-point restraint system including a first shoulder web, a second shoulder web, a first lap web, a second lap web, and a crotch web.

3. The occupant restraint system of claim **2** wherein:

the first electrically actuated web retractor is coupled to a proximal end portion of the first shoulder web;

the second electrically actuated web retractor is coupled to a proximal end portion of the second shoulder web; and the first and second web retractors and the sensor assembly are configured to fixedly attach to a rear portion of the seat.

4. The occupant restraint system of claim **1** wherein the individual electrically actuated web retractors comprise:

a base;

a spool rotatably mounted to the base and fixedly attached to a rotating shaft, wherein the spool is configured to wind, unwind, and/or lock the corresponding webs during operation;

a gear assembly operably coupled to a first end of the shaft;

a locking wheel operably coupled to a second end of the shaft, wherein the second end is opposite to the first end;

a DC motor operably coupled to the spool and configured to rotatably move the spool; and

a solenoid operably coupled to the spool configured to lock and unlock the spool in response to signals from the sensor assembly.

5. The occupant restraint system of claim **1** wherein the one or more acceleration sensors of the sensor assembly comprises:

a first acceleration sensor configured to sense vehicle accelerations in a forward and/or aft direction along an X-axis;

a second acceleration sensor configured to sense vehicle accelerations in a lateral direction along a Y-axis;

a third acceleration sensor configured to sense vehicle accelerations in a vertical direction along a Z-axis; and

an activation circuit configured to (a) disable the web retractors during normal vehicle operation, and (b) transmit the electrical signals to the web retractors when the vehicle experiences a dynamic event resulting in one or more vehicle accelerations above the predetermined threshold value.

6. The occupant restraint system of claim **1** wherein:

the first and second web retractors are configured to automatically tension the corresponding webs with a first force during a first dynamic event resulting in a first vehicle acceleration above the predetermined threshold value; and

the first and second web retractors are configured to automatically tension the corresponding webs with a second force greater than the first force during a second dynamic event resulting in a second vehicle acceleration above the predetermined threshold value, and wherein the second vehicle acceleration is greater than the first vehicle acceleration.

7. The occupant restraint system of claim **6** wherein the first and second web retractors are configured to automatically return the corresponding webs to normal or pre-event tension levels after the first dynamic event and after the second dynamic event.

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